Creating competitive factories – Speeding up the innovation process in factory design using Virtual Reality as a new engineering tool

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Abstract

This paper presents the participative approach in factory design and describes the system developed at the Fraunhofer-Institute for Factory Operation and Automation to support the factory planning and facility management process. When designing a new factory or revitalising old factory buildings important decisions have to be taken in an early stage of the planning process. The developed Model-Shop helps to speed up the planning process by supplying the owner, architect, process planner, construction planner and suppliers a common framework/environment for their decision-making process. Using Virtual Reality the interdisciplinary planning team can walk through the factory actively and discuss current planning options to achieve a higher quality level of decision in much shorter time.

Keywords

Competitive factory, Virtual Reality, participation, problem solving, creative, innovation, model-based-cognition process, decision making process, factory design center, factory planning

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35321-0_72

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1 INTRODUCTION

Changes in the environment makes it very difficult for companies to protect their vitality for the future [Warnecke, 1993]. There are a lot of influences and interests of customers, suppliers, staff and of course the company's shareholders. These impacts are constantly changing and the company must be aware of this. The changes of the indicators which are relevant for the production are getting more and more dynamic and complex: the causes are manifold and not reversible.

The goals of industrial production have been changed. The companies were focused on productivity goals during the previous years. But nowadays companies focus on the acceleration of their processes and increasing of their flexibility. The main reason for less profit while marketing a new product is because the product reaches its market with delay. This aim does not only concern the processes for product development but also the planning of production processes and the designing of organizations and factories [Kühnle, 1996]. It is accepted by all, that the life of a product becomes shorter and shorter. But it is only accepted by few that accelerated innovation cycles need completely new methodologies to design the organizations and factories.

Since new organizational concepts triggered out a revolution in enterprise cultures, the question of the best factory arises because of the increasing dynamics and complexity: This question arises not only once but continuously.

How do these changes affect the design and designing process of the factory?

All changes have to be considered in the production process and as well in the planning processes to cope with the new situation. Nevertheless, many factories are reactive, not proactive. Factory Planning is an important facet of the future direction of any enterprise, however, it is rarely seen as an urgent activity. This means that a planning process is triggered only if there is a necessity or a dissatisfaction [Hartmann, 1995]. But it should be a part in the continuous improvement process to protect the competitiveness. Ideally, factory planning is an iterative procedure with the task of continuous improvement in the field of manufacturing. Therefore, continuous measurement, fine-tuning and planning is necessary.

2 REQUIREMENTS ALLONG THE FACTORY LIFE CYCLE

The turbulence in the environment and the new thinking in design of dynamic organizations need a new way of thinking in factory design and operation. The cycle time of planning is getting very important. It changes from a unique concluded planning to permanent short cyclic designing. Planning becomes a continuous improvement process which has to be organized by all person concerned to point out all potentials and to get the maximum benefit.

The modifications of the classical factory planning essentially refers to the following factors: temporal horizon of the planning (strategic, tactical, functional), validity of the planning results (long-, mid- and short-time), executing the planning work (centralized, decentralized; internal/external), entrusting the planning task (utility planer, architect), kind of employee investment (information, questioning, dialogue, action) and cycle time of the planning task (unique-permanent).

Therefore it is necessary to identify different planning fields with specific goals and tasks along the factory life cycle. The life cycle of a factory starts with an idea or vision about the product, market or process and ends with the liquidation of the factory. In between the idea and the liquidation the factory can be seen as a learning center for all, the planers, the employees and the company's shareholders. Before running the company, the designing and realization has to be finished and the staff needs to be trained. Continuous improvements are the normal way of life in this new factory with dynamic organization structures. Changes have to be implemented into the company during the whole operation to adapt the factory on market demand and to be successful.

During the factory life cycle there are many impulses for changing because of the complex connections within the factory and its environment (see introduction). Different triggers for a factory planning can be: new technologies, changes of present products, new products which need new processes and structures or even new employees. The outcome of a successful factory planning project is to understand both, how the factory should look (layout, building) and how it should be run (operations, control).

3 CLASSIFICATION OF DIFFERENT DESIGN PROJECTS

The designing processes along the life cycle of the factory in a fractal company can be classified through three different indicators. A reasonable description can be the division according to:

- *Task* $A_{(old/new)}$ = objectives, goals, products, processes and technology of the factory,
- *Industrial building* $G_{(old/new)}$ = structure of the industrial building to fulfill the task A,

– *employee* $M_{(old/new)}$ = staff working in G to fulfill the task A.

These three indicators build a cube which can be used as a description model and allows a positioning of most different designing projects. Each designing project can be described through a vector existing of three dimension.

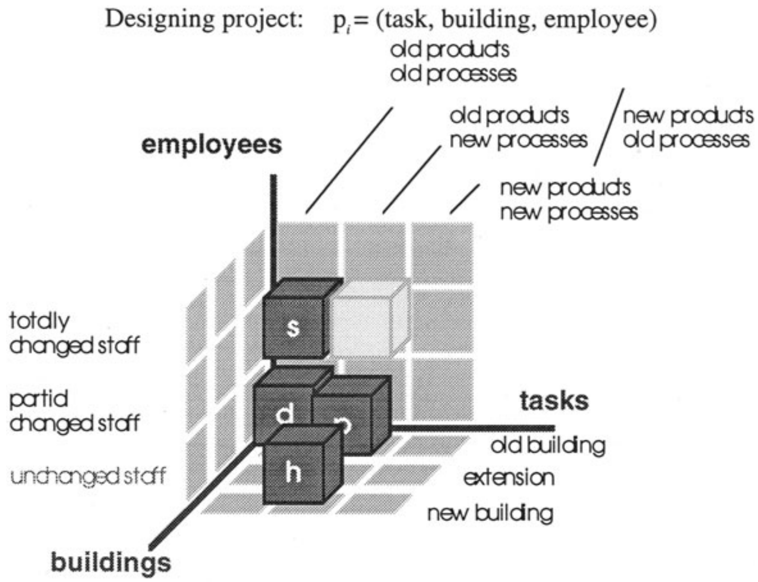

Fig. 2: Positions of projects in the classification cube [Mezger, 1996]

The axis of the classification cube can be described as follows:

- Axis employees: Planning a factory for new employees, the possibility of participative planning is very small, because the new staff has no know-how yet. They need training and qualification.
- Axis tasks: The need for simulation increases if there are new tasks or processes included in the planning project.
- Axis buildings: Designing new buildings, the visualization is one of the most needed tool during the process.

The position of a project within the classification cube gives information about the form and the degree of participation as well as the need of methods and tools to support the visualization and simulation. Examples:

- change projects $p_1 = (1, 1, 1)$,
- re-design projects: $p_2 = (1\text{-}2, 1, 1\text{-}2)$,
- brown field planning: $p_3 = (1\text{-}3, 2, 1\text{-}2)$,

– green field planning: $p_4 = (1\text{-}3, 3, 1\text{-}3)$.

4 THE MODEL-BASED COGNITION PROCESS

The problem solving process is characterized by learning through try and error. This logical approach and easy handling methodology is also used by common sense. This process is triggered by a problem or an astonishment [Popper, 1996]. Propper describes this problem solving process as a learning process through try and error with an three level schemata:

1. the problem
2. the alternative solutions
3. the elimination

This three level schemata is useful for the factory design process. The problem solving process in factory design starts with the formulation of the problem and is a three step process with goal clarification (situation analysis and goal formulation), the solution search and the selection (evaluation and elimination of solutions). Most important part of the problem solving process is the solution search, which is characterized by the continuing interaction of analytical and synthetic approach. [Wiendahl, 1996; Kühnle, Henn, 1996]. The most important issue of innovation in factory design and dynamic organization is to handle with astonishment [Wohland, 1996], because astonishment is the source for new ideas. It is important for the learning process to analyze the mistakes, look for reasons, be creative and create ideas for a better problem solving. Especially in factory and factory design scientists have probably devoted most of their energy to modeling structures and processes [Wiendahl 1994]. The main reason for this is a human characteristic:

> "People create and use cognitive models to predict behaviour and manipulate their surroundings in never ceasing attempts to fulfil their needs and achieve their goals."[Islo, 1993]

But models are not just required by people; they also form the basis for factory design. A wide variety of modelling methods is available as a basis for representing production systems. The appropriateness of a model is determined by its quality. The challenge in modeling is to create realistic model for simulation with an easy understanding description of the real world. The expense in time and costs is a function of complexity of the system, the degree of detail and the level of abstraction [Bracht, 1995]. To support the cognition process new tools and methodologies are necessary to integrate realistic models and realize a model based cognition process [Wiendahl, 1994].

The use of innovative software-tools for factory planning and organization design over all planning stages is very helpful. In addition to proven forms of employee involvement, e.g. information events, creative-workshops and programming [Henn, 1995] which guarantees a comprehensive participation, different 3D-CAD and CAP systems as well as software tools from the field of Virtual Reality (VR) are developed to improve the participation. The core idea in this concept of "Virtual Manufacturing" [Kimura,1993] is that parallel to the real world of the company, a virtual world is modeled which creates a test field for conducting experiments. A condition for the use of this virtual world is continuos comparison with the actual world and immediate adaptation of the models as appropriate. The observers can interact with and within the dynamic factory model. By seeing, hearing and feeling, the actor can discover and interpret the model and make decisions out of experiences. Using Virtual Reality the persons concerned can participate in the planning process. In education [Gausemeier, 1995] creates a Virtual Enterprise (using VR) to explain all the business processes in a company.

5 VIRTUAL REALITY TO SUPPORT THE DESIGN PROCESS

The previous approaches in using VR put their priorities only in visualization to show complex connections realistic and to make the understanding of complicate facts more easy. They do not focus on the aspect of designing actively and to create and assess solutions. New tools are necessary to support the partizipative factory design process and the ongoing improvement cycle as well. Therefore, the Fraunhofer-Institute for Factory Operation and Automation developed the Model-Shop Factory Design to design, to visual and to simulate the complete company in a virtual world by a partizipative process.

5.1 Modell Shop Factory Design

Aim of this idea is to include all persons, which participate in the factory planning (architect, operator, owner, worker), in the organization process. Therefore, it sets Virtual Reality for the model formation and visualization onto the effort of an understandable representation of all elements and performing connections of a factory. These VR-models serve as a common planning basis over all planning stages and are to be used continuously for all utility disciplines. The observers can interact with and within the dynamic company model. By seeing, hearing and feeling, the actor can discover and interpret the model and make decisions out of experiences. This allows the development of an information potential by a verification by interaction of all participants. Homogeneous models result as a platform for the interdisziplinary dialog and the discussion of all participants. As a result, many knowledge carriers are linked into the extraction and the processing from information on decision-making, which leads for an efficient workmanship of distributed knowledge. Mistakes in the model are uncovered by common experiments and simulations. This allows to reach unambiguous statements and the derivation of unequivocal decisions. Typical performance goals using Virtual

Reality in the planning process is a more secure and accelerated planning process with higher quality. Also the process is cheaper and the information is available in an early state to make decisions more reliable.

The creation process starts with the modelling of the real system. To understand how the factory should be organized (organization units), how it should be run (operations, control) and how it should look (layout) an integrated modeling of the factories (plants and buildings) and the processes is necessary for a successful realization. Through interaction with and within the model, the planner gets a lot of information and knowledge. Interpreting the results, he either can validate the model or transfer the consequences into the real system to improve it. The creation process can be devided into two major parts. One is the Knowledge Acquisition part, in which experiences can be made and information defects are shown in an early stage. Through discovery and experience knowledge is generated within the virtual model to build up a knowledge database. The knowledge utilisation part is to transfer the benefits, if needed, into the real system.

Important is the understanding that a VR-model does not replace the creative traditional factory planning tasks, because it is only as detailed as the different models in mind of all participants. But it could be used like a platform for a dialogue between the different disciplines of planning in which new ideas could be discussed and worked out. Although the information which is needed additional for a successful planning could be pointed out.

5.2 Mod!Fact - An interactive software for factory planning

For the planning of factories in Virtual Reality, the Fraunhofer-IFF developed Mod!Fact as an interactive planning and intuitive tool. The subrack panels suffice for projecting different layout variants up to the integrated organization of complex factories and plants, inclusive for the evolution of alternative development concepts within the framework of general development from the first one.

Essential sign of Mod!Fact is - in addition to the effort of Virtual Reality - an integrated concept overall, that the usual procedure for layout design and improvement unities with innovative methods for the formation of spatial-organizational structures to a continuous tool. In this case, improvement in the information and communication relationships is in the foreground in addition to the optimization of the flow of materials and an afterwards arrangement and structuring of the resources. Effects after this, according to the design of the building, one can vary and check it in a conditional manner. The results won in the respective stages are available for all planning stages.

In addition, Mod!Fact has an integrated structure simulator which accepts the data from model formation and values them dynamicly. The link-up of simulation and animation directly with Virtual Reality allows a clear and significant representation of complex processes. In the scenery, progressing processes not only can be judged by qualitative criteria but also be evaluated to quantitative factors. In this case, the use of Virtual Reality as an interactive user interface allows manipulating acting processes directly in the model. Modifications immediately become visible and can be analyzed and evaluated without further expenditure.

6 EXAMPLES OF INDUSTRIAL PROJECTS WITH MOD!FACT

The position within the classification cube describes the specialies and requirements in use of MOD!FACT in these different examples. In the claasification cube we are identify four succesful indsutrial projects as references for the use of MOD!FACT

– re-design project	drilling machine factory	d = (1,1,1)
– brown field project	pharmaceutical production unit	p = (1,2,1)
– green field project	honey factory	h = (2, 3, 1)
	salad factory	s = (2, 3, 3)

6.1 Pharmaceutical Enterprise - Re-design of a production unit

The goal of this project was in the redesign of an available production field of a pharmaceutical enterprise. A part of the production should be shifted into another already existing manufacturing hall. To increase the acceptance of a future solution as well as of its consistent transformation the present solution should be judged and improved by including the affected employees. The result should be a layout, elaborated together.

In this case, the development of the motivation factor by integration of all employees was considered to be essential. For the carrying out of the project the relevant information for modeling was gathered, starting from the real system, by integrationt of the employees as soon as the goal were determined. The information and results determined together with the employees represented the basis for modeling the future production field with the aid of the Model-Shop Factory Design and MOD!FACT. The level of detail necessary for model formation and the communication degree were defined on this basis. The VR-model was generated in accordance with the made aims and orders. In this case, the VR-model was generated and prepared in such a way that it could be measured by means of communication of the shared team members on the formulated aims. Following modeling, the actual finding extraction occurred. Different solution scenarios were tested by communication of all shared collaboration with the model, whose results represented statements about the model. As a result, the model could be used for knowledge transfer between the planning group and every individual employee.

6.2 Honey Factory - Planning of a new production site

Aim of this project was to support the design and realization process for new a factory new for the treatment of honey by the Model-Shop Factory Design and MOD!FACT. The models to be elaborated should represent the different solution alternatives worked out by all people involve to the planning process in an understandable way. Moreover they should offer the possibility, to allow diverse experiments by modifications of partial aspects, in order to develop and correct the current models. Modeling the new factory formed the basis for the common design of the factory by investigating every knowledge carrier as every architect, utility planer, plant supplier, decision maker but also the own employee. Therefore, the integrated illustration of the new factory was in the foreground in order to be able to represent the future situation vividly and to allow an evaluation with regard to building equipment, room use, operations and systems engineering.

Starting point for the model preparation was the reunion and preparation of the plans and of the information elaborated in the different planning groups (architect, utility planer etc.). On the basis of this material, the generation of a first coarse model in Virtual Reality occurred. Therefore the planned building substance in connection with the already available buildings was to be visualized on the one hand as soon as to represent the required machines and plants in accordance with the planning state. In the following process of the project the information from the current factory organization process was treated and integrated into the model correspondingly. The achieved planning state was valid to check it and to verify it together with all planning participants and to modify if necessary. In short term succeeding workshops and in an iterative procedure a precise and verified planning state was achieved, which was borne by all participants. A knowledge increase that led to a sufficient state of cognition at shortest time was implemented by the interpretation of the results elaborated into the workshops, to derive consequences for the organization of the new factory and to take secured decisions within the framework of the current organization process.

7 CONCLUSIONS

Systems design for dynamic organization and factories have to be considered a continuing task which needs the input of all the people in the hierarchy. It has to take into account that the important continuous improvement process is only possible using the human potential. Therefore, intelligent and intuitive tools are needed to support this interactive process and reach the whole potential. Those tools have to create a test field for conducting experiments and testing new ideas in the virtual world by making mistakes and developed them to innovations before implementation in the real world. The realization of MOD!FACT clearly demonstrates this virtual experiments approach in projects and the efforts in factory design with an participate approach.

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